

solution, as well as the flow of inert gas. It is an advantage to make this distance variable. In all cases the diameter of the electrospray chamber should be at least twice the capillary to end plate distance, and preferably larger, but if the chamber is too large, the quantity of inert gas required becomes too great.

The voltages applied to the focussing electrodes are adjusted to optimum ion generation in the electrospray and to ensure a stable spray. Typical conditions for the generation of positive ions are:

$$V_{14}, V_{15} = +6 \text{ KV,}$$

$$V_{12}, V_{13} = +1.5 \text{ KV,}$$

$$V_{17}, V_{11} = +1.0 \text{ KV,}$$

$$V_1, V_5 = +100 \text{ V,}$$

where the subscript numbers refer to the electrodes identified by those numbers in FIG. 1, and the voltages are all relative to the housing 19 which is at earth potential.

The conditions over which stable electrospraying can be achieved can be extended by heating the capillary by passing an electrical current through it, as described. FIG. 3 is a drawing of the electrospray jet as it leaves the tip 31 of the needle 30. It consists of a small cone of liquid 37 which extends through the distance 36 to point 38. The true electrospray jet 39 starts at point 36, as shown. It is thought that heating the capillary reduces distance 36, which results in the formation of stable jets over a wider range of capillary internal diameters and flow rates, etc. It also results in greater ion currents when very small bore capillaries are used, and improves the overall efficiency of the process. However, it is possible that some thermal degradation of sensitive samples might be caused by heating the capillary.

There are some limitations on the flow rate and composition of the solution if successful electrospraying is to be obtained. Flow rates between 1 and 100 microliters per minute can be used, but in general the best results are obtained at the lowest flow rate. The solvent should be such that there is either electron or proton affinity with the expected samples, and it should be polar and preferably contain an ionic solute in addition to the sample. These requirements mean that when used as a liquid chromatograph—mass spectrometer interface, the electrospray source works well with highly polar solvents such as water or methanol, especially when the solvent contains additional dissolved salts such as buffers, in contrast with most other forms of LC-MS interfaces.

The inert gas introduced into the source should preferably consist of a fairly pure gas such as nitrogen, helium, or argon, etc. As explained, the degree of desolvation of the ions can be varied by adjusting the flow rate of the gas and its temperature. The flow rate required for a particular degree of desolvation is of course dependent on the liquid flow, and typically a flow of 200 at.cc.s<sup>-1</sup> is used for a liquid flow rate of 10 microliters per minute, at a temperature of 60° C. to ensure complete desolvation. Flow rates from 50 to 500 at.cc.s<sup>-1</sup> and temperatures from 25° C. to 100° C. can be used, however.

The ions generated in the electrospray process pass through orifice 4 in skimmer 5 into an evacuated region in housing 19 where the pressure is maintained at 10<sup>-3</sup> torr or less by a vacuum pump connected to port 21.

The electrical potential applied to end plate 1 is adjusted to obtain optimum transmission of the ions. Additional electrostatic lens elements can be provided behind orifice 4 for additional focussing of the ion beam if desired. Alternatively, means can be provided in this region to accelerate the ions to another kinetic energy, as described previously.

The focussed ion beam then passes through an orifice in a second skimmer 23 into a region of still higher vacuum which contains the mass spectrometer 29. Unless means are provided for reaccelerating the ions, this must be a mass filter capable of accepting ions with very low energies, such as a quadrupole analyser. The potential on plate 22 which supports the skimmer is also made variable to assist in focussing the ion beam, and more electrostatic lenses 28 are provided to ensure maximum efficiency of transmission of ions into the spectrometer. Typically, for a quadrupole analyser, plate 22 and the first element of lens 28 will be maintained at about +25 V, for the conditions given previously. This potential determines the energy with which the ions enter the spectrometer. The second skimmer is provided to allow a higher vacuum to be maintained in the region of the mass spectrometer whilst maintaining an efficient transfer of ions, and devices of this type are well known.

It will be appreciated that the source described above is intended by way of example only, and that it is possible to construct an electrospray source incorporating the invention in a variety of alternative ways, which will be apparent to those skilled in the art.

What is claimed is:

1. In a method of generating ions for mass spectral analysis from a sample dissolved in a solution by electrospray ionization the improvement comprising:

- (a) causing said solution to flow through a capillary tube or jet;
- (b) maintaining a high electrical potential difference between said capillary tube or jet and a first conductive wall spaced from and disposed facing the outlet of said capillary tube or jet thereby causing said solution to be electrosprayed from said outlet;
- (c) maintaining the ambient pressure between said outlet and said wall at substantially atmospheric pressure;
- (d) providing between said wall and said outlet a flow of inert gas substantially counter to the flow from said outlet;
- (e) providing an orifice in said wall in alignment with the axis of said capillary tube or jet at the outlet thereof; and
- (f) maintaining the pressure on the side of said wall remote from said outlet at a reduced pressure whereby gas containing ions from said solution characteristic of said sample flows through said orifice.

2. A method according to claim 1 wherein gas and ions flowing through said orifice away from said outlet are subsequently subjected to one or more additional pressure reduction, focussing or ion accelerating operations prior to the mass spectral analysis of the ion beam so generated.

3. A method according to claim 1 in which the flow rate of the inert gas is varied to control the degree of desolvation of the ions formed by the electrospray process.

4. A method according to claim 3 in which the flow rate of the inert gas lies within the range 50–500 at.cc.s<sup>-1</sup>.